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**METHOD FOR INCORPORATING POLYTETRAFLUOROETHYLENE
(PTFE) INTO SYNTHETIC MELT SPUN FIBERS TO PRODUCE FIBERS
AND TEXTILES HAVING IMPROVED PROPERTIES**

SPECIFICATION

5

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority from U.S. Provisional Patent Application No. 60/415,039 filed October 1, 2002, the disclosure of which is
10 incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention generally relates to a method for incorporating highly dispersible polytetrafluoroethylene (PTFE) powder into synthetic melt spun
15 fibers so that the resulting fibers have the improved properties generally associated with PTFE, including, for example, low coefficient of friction, improved wear resistance, improved stain resistance and improved light stability and UV-light resistance, when compared to conventional melt spun fibers. The present invention further relates to melt spun fibers made by the method described herein and textiles,
20 fabrics, and articles of manufacture, made from these synthetic melt spun fibers

BACKGROUND OF THE INVENTION

In the textile industry, apparel manufacturers and fiber producers are
25 constantly trying to modify the basic composition of each generic type of synthetic fiber, both chemically and physically, in order to produce fiber variations which provide softer feel, greater comfort, brighter and longer lasting colors, better warmth or cooling, better moisture transport or wicking, and better blending properties when blended with other fibers. "FabricLink, Fabric University – Fabric Producers and
30 Trademarks," <<http://www.fabriclink.com/Producers.html>>. Thus, a constant need exists in the art of fiber production for new and innovative ways to improve the properties of synthetic fibers.

Various manufacturing processes are known in the art for making synthetic fibers. Many synthetic fibers are created by extrusion, whereby a thick viscous liquid polymer precursor or composition is forced through the tiny holes of a spinneret to form continuous filaments of semi-solid polymer. As the filaments
5 emerge from the holes of a spinneret, the liquid polymer is converted first to a rubbery state and then is solidified. The process of extruding and solidifying filaments is generally known as spinning. Common methods of spinning filaments of melt-spun synthetic fibers are generally referred to as "melt spinning."

Typically, for melt spinning processes, a fiber-forming substance is
10 melted to a viscose liquid state for extrusion through the spinneret. After extrusion from the spinneret the fiber material or filament is solidified by air-cooling. Fibers typically formed by melt spinning include polyester, nylon, and polypropylene, among others.

Polyester fiber, one of the more common melt spun fibers, is defined
15 by the Federal Trade Commission as a manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid. Polyester fiber is commonly produced by extruding (or spinning) a polyester melt at a high pressure (for example, 3,000 psig) and a high temperature (for example, 500° F) through spinnerets having
20 multiple openings. Once extruded, the polyester fibers are drawn and textured to the desired fiber characteristics. Micro contaminants are removed from the molten polyester stream or feed prior to fiber spinning to preclude blockage of the small spinneret holes, which are typically about 25-500 μm in diameter. For low denier fibers, even small size contaminants or particles must be removed from the melt prior
25 to extrusion. "Pall Corporation – Polyester Fiber Production,"
<<http://domino.pall.com/www/weblib.nsf/pub/354559E3AFA95F9885256863004BF4C4?opendocument>>

Additives (e.g., dyes and surfactants) may be added to the polymer or fiber-forming substance (such as a polyester melt) prior to extrusion in order to
30 improve the quality or characteristics of the resulting melt spun fibers. Until the present invention, however, it has not been shown that the addition of

polytetrafluoroethylene (PTFE) powder (where the powder is dispersible to low micron or submicron particle size or where the PTFE powder particles have a primary particle size that is low micron or submicron range) to the fiber-forming substance may be of any benefit in forming improved melt spun fibers.

5 It is generally known that PTFE provides characteristics such as improved slipperiness and non-wettability to materials into which it is incorporated. PTFE is useful when in a powder form or an aqueous or organic dispersion form for this purpose. Dry PTFE powder products are known in the art and are generally available in the industry. Several manufacturers in the fluoropolymer industry
10 produce PTFE powders, and some of these manufacturers describe the PTFE particle size in their powders as being "submicron" or capable of being dispersed to submicron size.

 A wide array of end uses exists for small particle size or submicron PTFE. For example, small amounts (e.g., about 0.1 to 2% by weight) of powdered
15 PTFE may be incorporated into a variety of compositions to provide the following favorable and beneficial characteristics: (i) in inks, PTFE provides excellent mar and rub resistance characteristics; (ii) in cosmetics, PTFE provides a silky feel; (iii) in sunscreens, PTFE provides increased shielding from UV rays or increased SPF (sun protection factor); (iv) in greases and oils, PTFE provides superior lubrication; and (v)
20 in coatings and thermoplastics, PTFE provides improved abrasion resistance, chemical resistance, weather resistance, water resistance, and film hardness.

 Other, more specific end uses for submicron PTFE powders and dispersions include: (i) incorporating a uniform dispersion of submicron PTFE particles into electroless nickel coatings to improve the friction and wear
25 characteristics of such coatings (Hadley et al., *Metal Finishing*, 85:51-53 (December 1987)); (ii) incorporating submicron PTFE particles into a surface finish layer for an electrical connector contact, wherein the PTFE particles provide wear resistance to the surface finish layer (U.S. Patent No. 6,274,254 to Abys et al.); (iii) using submicron PTFE particles in a film-forming binder as a solid lubricant in an interfacial layer,
30 wherein the interfacial layer is part of an optical waveguide fiber (U.S. Patent No. 5,181,268 to Chien); (iv) using a submicron PTFE powder (along with a granulated

PTFE powder and TiO_2) in a dry engine oil additive, wherein the additive increases the slip characteristics of the load bearing surfaces (U.S. Patent No. 4,888,122 to McCready); and (v) combining submicron PTFE particles with autocatalytically-applied nickel/phosphorus for use in a surface treatment system for metals and metal alloys, wherein the PTFE imparts lubrication, low friction, and wear resistance to the resulting surface ("Niflor Engineered Composite Coatings," Hay N. International, Ltd. (1989)). Additional specific examples of end uses for PTFE involve incorporating PTFE into engine oils, using PTFE as a thickener in greases, and using PTFE as an industrial lubricant additive. Willson, *Industrial Lubrication and Tribology*, 44:3-5 (March/April 1992).

For many applications or end uses incorporating submicron PTFE powders and submicron PTFE dispersions (such as the end uses described above), the beneficial effects imparted to the application or end use system derive from the chemical inertness of the PTFE particles and/or the low coefficient of friction of the PTFE particles. In addition, submicron PTFE particles that have a low particle size, possess a significantly higher ratio of active surface area to weight when compared to larger PTFE particles. Thus, submicron PTFE particles are better able to propagate their beneficial effects to a desired application system than the same weight of larger size PTFE particles.

In light of the above discussions of the constant need in the fiber industry for making synthetic fibers having improved properties and the usefulness of PTFE in various applications, it is evident that a need exists in the art for a convenient and inexpensive method by which PTFE, specifically PTFE powder that is dispersible to low micron or submicron particle size, may be incorporated into a fiber-forming substance so that, for example, fibers that are spun by a melt spinning process possess the improved properties associated with PTFE. Furthermore, a need exists for a method of incorporating low micron or submicron PTFE particles uniformly and permanently throughout a melt spun fiber (as opposed to mere surface coatings) so that textiles, fabrics and clothing made from such fibers will not lose, over time, the beneficial properties associated with PTFE due to surface wear and tear. The present invention addresses these and other needs.

SUMMARY OF THE INVENTION

The present invention relates to a novel method by which
5 polytetrafluoroethylene (PTFE) is incorporated into a synthetic melt spun fiber so that the resulting fiber has many improved properties when compared to conventional melt spun fibers. In the present method, PTFE powder that is dispersible to low micron or submicron particle size is incorporated into the desired fiber-forming substance (such as a polyester melt) from which filaments or fibers are made by a melt spinning
10 process. The resulting "PTFE-enhanced" melt spun fibers have PTFE particles dispersed through out their filament bodies. These PTFE-enhanced melt spun fibers in which PTFE is incorporated directly into the filament bodies have improved properties associated with PTFE. For example, the melt spun fibers resulting from the method of the present invention may exhibit a significant decrease in the coefficient
15 of friction when compared to conventional melt spun fibers.

The use of low micron or submicron particle size PTFE powder as an additive to the polymers or fiber-forming substances used to make certain synthetic fibers is important in that the PTFE improves the non-wetting properties of the fibers and textiles made from such fibers. Thus, fibers incorporating PTFE may be useful in
20 making textiles that are used for making industrial filtration and dewatering devices. Such fibers incorporating PTFE also may be advantageously used in producing carpets, fabrics for sportswear and outerwear, hot-air balloons, car and plane seats, umbrellas, and the like. Furthermore, the fibers of the present invention also may be advantageously used to make tightly woven fabrics that are used in parachutes, boat
25 sails, and similar applications. The combination of a tight weave and water shedding may provide a textile or clothing fabric that is both water shedding and breathable. The incorporation of PTFE into such textiles may result in other advantages, such as the textile articles being easier to clean.

The method of the present invention is useful in that the resulting
30 PTFE-enhanced melt spun fibers have several improved properties when compared to conventional synthetic melt spun fibers. The improved properties include but are not limited to the following: lower coefficient of friction; reduced wettability; improved

stain resistance; improved washability; improved opacity; enhanced protection from ultraviolet (UV) radiation (which increases the light-fastness and the lifetime of the fiber or fabric); increased color fastness; reduced gas permeability; better abrasion resistance; tighter weave; improved wear index; increased flexibility of the fiber;
5 decreased scroop (where scroop generally refers to sounds of rubbing made by certain fabrics); and lowered amounts of wrinkling when the PTFE-enhanced fibers are incorporated into a fabric or clothing article.

Additionally, not only does the method of the present invention result in improved melt spun fibers, but also the method serves to significantly improve the
10 overall processes by which melt spun synthetic fibers are typically made. For example, the increased lubricity or slipperiness of the fiber-forming substance due to the addition of PTFE in it may result in lower production times for fiber production, significantly increased processing speeds, increased throughput rates and overall production rates. The increased lubricity of the fiber-forming materials due to the
15 PTFE addition also may give a longer lifetime to the fiber-making equipment, and provide overall savings in energy that is expended in running the fiber-making equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

20 FIG. 1 is a bar graph comparing the tensile strength of PTFE-enhanced fibers prepared in accordance with the present invention and conventional fibers ,after both were exposed to radiation.

FIG. 2 is a bar graph illustrating the relative tensile strength of the
25 fibers of FIG. 1

FIG. 3 is a bar graph illustrating the static and kinetic coefficients of friction of a fabric made of PTFE-enhanced fibers prepared in accordance with the present invention and the static and kinetic coefficients of friction of a fabric made of conventional fibers.

30 FIG. 4 is a bar graph comparing the static and kinetic coefficients of friction of another fabric made of PTFE-enhanced fibers prepared in accordance with

the present invention and the static and kinetic coefficients of friction of a fabric made of conventional fibers.

DETAILED DESCRIPTION OF THE INVENTION

5 The present invention relates to a method for producing improved melt spun fibers, wherein the fibers are more wear resistant and have a lower coefficient of friction than melt spun fibers that are known in the art. The method of present invention improves the quality of a melt spun fiber by introducing PTFE that is dispersible to low micron or submicron particle size into the polymer or fiber-forming
10 substance as a fiber is being formed by a melt spinning process. The PTFE-enhanced melt spun fibers that are produced by the method of the present invention exhibit, among other properties, increased wear resistance, stain resistance, water resistance, and a significantly decreased coefficient of friction, when compared to conventional melt spun fibers known in the art.

15 A result of the present invention is the incorporation of PTFE throughout a melt spun fiber so that the fiber material contains a homogeneous distribution of PTFE particles. This may be contrasted with processes and fibers known in the art where PTFE is applied only on the surface of melt spun fibers or only on the surface of a fabric made from melt spun fibers and thus can wear away.

20 In preferred embodiments of the method of the present invention, the following types of PTFE are useful: PTFE powder that is dispersible to submicron particle size; PTFE powder that is dispersible to low micron particle size; aqueous or organic dispersions of PTFE powder that is dispersible to submicron particle size; and aqueous or organic dispersions of PTFE powder that is dispersible to low micron
25 particle size. One specific type of PTFE that may be useful in the method of the present invention is the PTFE described in co-assigned International Patent Application No. PCT/US03/07978 filed on March 14, 2003, which is hereby incorporated by reference herein in its entirety.

30 In the present description, the designation "submicron particle size" indicates that a given quantity of PTFE powder disperses in isopropyl alcohol (IPA) such that more than about 90%, preferably, more than about 95%, and more

preferably, more than about 99% of the PTFE particles have a particle size that is less than about 1.00 μm . Furthermore, the designation "low micron particle size" indicates that a given quantity of PTFE powder disperses in isopropyl alcohol (IPA) such that about 95% or more of the PTFE particles have a particle size that is less than about
5 10.00 μm .

The dispersibility of the PTFE powder down to low micron or submicron-sized particles may be important for unhindered practice of melt spinning processes. These small size PTFE particles may pass through spinneret holes with ease, unlike large sized PTFE particles that can clog spinnerets making fiber
10 formation difficult. It is also envisioned that the method of the present invention allows for PTFE that is dispersible to low micron particle size to be used in higher denier fibers, while PTFE that is dispersible to submicron particle size will be useful for forming both low and high denier fibers. The PTFE particles may be uniformly or homogeneously dispersed through the bodies of the fiber of any denier size.

The dispersibility of the PTFE particles in a powder may be determined by dispersing an amount of the PTFE powder in isopropyl alcohol (IPA). Then by conventional particle size analysis (e.g., light scattering analysis), an indication of the mean particle size and the particle size distribution of the PTFE powder may be obtained. Thus a user can verify or confirm, for example, if a sample
15 of PTFE powder is completely (100%) dispersible to submicron in size or is otherwise suitable for use in melt spinning processes.

As mentioned above, aqueous or organic dispersions of PTFE powder, where the powder is dispersible either to submicron particle size or low micron particle size, may be used in the method of the present invention. PTFE dispersions
25 that are most useful in the present method typically comprise from about 20% to about 60% PTFE by weight. Alternatively, dry PTFE powder that is dispersible either to submicron or low micron particle size may be dispersed directly into the fiber-forming substance.

Fiber-forming polymer substances that are contemplated for use in the
30 present invention include but are not limited to polyester, nylon, and polypropylene, among other fiber-forming thermoplastic resins.

In certain preferred embodiments, PTFE powder that is dispersible either to low micron or submicron particle size is first provided. Subsequently, the PTFE is incorporated into the fiber-forming polymer to be used in making the melt spun fibers. In a typical embodiment, poly(ethylene) terephthalate (PET) may be used
5 as the fiber-forming polymer.

The submicron or low micron dispersible PTFE powder is incorporated into the fiber-forming polymer (such as PET) in three primary ways: 1) the dispersible PTFE powder is introduced and dispersed directly into the fiber-forming polymer in its dry powder form; 2) the dispersible PTFE powder is introduced into the
10 fiber-forming polymer in the form of an aqueous or an organic dispersion; or 3) the dispersible PTFE powder is introduced into the fiber-forming polymer in the form of a pelletized master batch. Essentially, the highly dispersible PTFE described herein may be introduced at any stage of a melt spinning process for making fibers prior to the fiber-forming polymer going through the spinneret.

15 With respect to the third way of incorporating PTFE mentioned above, a pelletized master batch of PTFE is formed and incorporated into the fiber-forming polymer in the same manner that master batches of pigments or flame retardants are formed and incorporated into melt spun fibers. In certain embodiments, the introduction of the highly dispersible PTFE in the form of a pelletized master batch is
20 preferred. The master batches of PTFE in a fiber-forming polymer that are useful in the present invention typically comprise about 5% to about 60% PTFE, and more particularly about 40% to about 45% PTFE.

This introduction of highly dispersible PTFE powder into a fiber-forming polymer results in improved flow characteristics during extrusion, improved
25 production rates, and significantly decreased production times because of the lubricity added to the overall fiber-forming process.

In certain embodiments, the melt-spun fibers that are made according to the present invention are thin fibers, having a denier of less than about 10. However, thicker, coarse melt spun fibers also may be produced having PTFE
30 incorporated therein.

The PTFE-enhanced melt spun fibers produced by the method of the present invention may be incorporated into a fabric or a textile, whereby the fabric or textile has the enhanced properties typically associated with the addition of PTFE to articles or compositions. For example, fabrics or textiles made with the fibers of the present invention can exhibit a significantly decreased coefficient of friction. Fabrics or textiles with such properties may be useful for making apparel intended for wear in sports or recreational activities. Other desirable properties of the PTFE-enhanced melt spun fibers of the present invention, for example, include the exceptional wear resistance and stain resistance exhibited by the fibers, the light-fastness and UV-ray resistance of the fibers, the colorfastness of the fibers, and the resistance to degradation of the fibers.

Specifically, the PTFE-enhanced fibers and/or the fabrics made from the PTFE-enhanced fibers of the present invention may be wear tested to determine the wear resistance of the fibers. The wear testing may include Taber testing, Mace testing, and Pilling tests. Similarly, tests may be performed to determine the tenacity of the fabric, the elongation of the fabric, and the draw. Generally, the same full range of tests that are commonly used in the industry to analyze the properties of melt-spun fibers may be employed to test the fibers of the present invention. Tests used in other industries and other scientific test methods can also be used to characterize the fibers and fabrics of the present invention.

In some embodiments of the present invention, it may be desirable to form bicomponent fibers using the present method of incorporating PTFE into the fiber-forming polymer resin during the spinning of synthetic bicomponent fibers. Bicomponent fibers are generally described as fibers, which comprise two polymers having different chemical and/or physical properties extruded from the same spinneret with both polymers within the same filament. Typically, the advantages afforded by bicomponent fibers include thermal bonding of the two polymers, self-bulking of the fibers, the ability to make fibers having unique cross-sections, and the ability to reap the benefits of special polymers or additives at a reduced cost.

Most commercially available bicomponent fibers have one of the following configurations: sheath/core; side-by-side; or eccentric sheath/core.

However, any bicomponent fiber configuration may benefit from the method of the present invention. Typical polymer combinations used in the synthetic fiber industry to make bicomponent fibers include: fibers having a polyester core with a copolyester sheath; fibers having a polyester core with a polyethylene sheath; and fibers having a
5 polypropylene core with a polyethylene sheath.

In certain embodiments of the present invention where bicomponent fibers are sought, it may be possible to make fibers having sheath/core configurations where a polymer, such as poly(ethylene) terephthalate (PET), is used as the core, while the sheath contains a polymer (such as PET) having highly dispersible PTFE
10 particles incorporated therein according to the present method. For example, in certain embodiments, bicomponent fibers are made wherein the sheath contains from about 2% to about 40% or more PTFE. Several advantages of bicomponent fibers formed according to the present method include retained tensile strength, since the core of the fiber remains very strong, as well as decreased cost because PTFE is
15 incorporated only in the sheath portion of the fiber.

The method and compositions of the present invention may be better understood through the working Examples detailed below. Additionally, several of the improved properties of the PTFE-enhanced melt spun fibers of the present invention are discussed in more detail below in the working Examples. These
20 Examples are not intended in any way to limit the disclosure of the present invention, but are meant to illustrate certain embodiments and features of the method and the fibers disclosed by this invention.

EXAMPLES

Example 1: Rub Testing of Fabrics Made with PTFE-Enhanced Melt Spun Fibers

In the present Example, a rub test was performed to compare the
30 properties of one knitted sleeve made from melt spun fibers in which PTFE had been incorporated into the fibers according to the present method, and another knitted sleeve made from conventional melt spun fibers that did not have any incorporated PTFE.

Various rub tests exist in the art for determining the wear resistance, slipperiness, and overall frictional behavior of melt spun fibers. During this Example, it was determined that a specific, very sensitive type of rub testing that is typically used with printing inks (according to ASTM D-5181) provided a straightforward and definitive method of testing the wear and the frictional characteristics of these knitted sleeves. This rub test method, which may performed using a Sutherland Ink Rub Tester, was suitably adapted in this Example for use with fabrics made from melt spun fibers. This rub test may be as sensitive or possibly even more sensitive to a trained operator than the other standard rub tests that are typically used in the fiber or textile industry.

Specifically, the synthetic fibers used to make the sleeves for this Example were made of PET, the polymer discussed in detail above that is typical for making polyester fibers. For Sleeve 1, PTFE that is dispersible to low micron or submicron particle size was incorporated into the PET polymer resin so that after the PTFE-enhanced polyester fibers were formed and manufactured into a sleeve, the amount of PTFE in the resulting sleeve was about 5% by weight. The denier of the PTFE-enhanced fibers was 240, and the Denier Per Filament (DPF) was 7.06.

Sleeve 1 was knitted from the inventive PTFE-enhanced polyester fibers, using 4-inch cylinders and 144 needles in a jersey knit fashion. For Sleeve 2, no PTFE was incorporated into the PET polymer resin used to make the polyester fibers that made up that sleeve. The polyester fibers used in Sleeve 2 were melt spun in the same fashion as Sleeve 1. Also, Sleeve 2 was knitted in the same jersey knit fashion as Sleeve 1.

Rub tests were then performed on both sleeves to determine the abrasion resistance of each of the sleeves. The rub test was conducted using a Sutherland Ink Rub Tester. In the tester a 4-pound weight was rubbed over each sleeve at "slow speed" (i.e., 32 cycles per minute).

During the testing, a Standard Receptor Stock (#5 ASTM D-1581) first was secured to the 4-pound weight. Sleeve 1 was then placed on the pad of the Sutherland Ink Rub Tester. The Standard Receptor Stock was placed over Sleeve 1 and was secured by the weight arm of the Ink Rub Tester. Then, the number of

strokes was set to 450 and the rub abrasion test begun. After completion of 450 strokes, the 4-pound weight was removed from the fabric. The same testing procedure was used for Sleeve 2.

5 Sleeves 1 and 2 were visually compared to determine the level of abrasion caused by the rub test. Specifically, the sections of each sleeve that were rubbed by the Standard Receptor Stock, was visually scrutinized to determine which sleeve had a lower number of scratches. It was determined that the knitted sleeve Sleeve 1 (made of 5% PTFE content fiber) showed fewer scratches than Sleeve 2 (made of 0% PTFE content fiber). These results illustrate the improved abrasion
10 resistance imparted to fibers by the incorporation of PTFE.

Example 2: Rub Testing of Fabrics Made with PTFE-Enhanced Melt Spun Fibers

15 In this Example, Sleeves 3 and 4 were formed in exactly the same manner as Sleeves 1 and 2, respectively, discussed in Example 1 above. Thus, Sleeve 3 was made of polyester fibers in which PTFE has been incorporated whereas Sleeve 4 was made of conventional polyester fibers. In this Example, rub testing using the Sutherland Ink Rub Tester was again performed. However, in this Example, the
20 performance of each sleeve was measured against a reference printed film of Blank Magenta Ink having no wax.

 Sleeve 3 and Sleeve 4 were processed through the Sutherland Ink Rub Tester using the same general procedure (slow speed and weights) as described above in the context of testing Sleeve 1 and Sleeve 2 (Example 1). However, in this
25 example, the reference printed film was first placed on a pad in the tester. The test sleeve (Sleeve 3 and then Sleeve 4) was secured to the 4-pound weight and rubbed against the reference printed film for 450 strokes. After the rubbing strokes, Sleeves 3 and 4 were visually inspected to assess the number of scratches on them. The reference printed film was similarly inspected to assess damage to it. Visual
30 observations showed that Sleeve 3 had less scratches on it than Sleeve 4. Further, Sleeve 3 had caused less damage to the printed ink film than did Sleeve 4. These results indicate that Sleeve 3 having PTFE- enhanced fibers has superior abrasion

resistance than Sleeve 4 having conventional melt spun fibers, which comprises no PTFE.

5 **Example 3: Coefficient of Friction Testing of Fabrics Made with PTFE-Enhanced Melt Spun Fibers**

10 In this Example, testing was performed to determine and compare the kinetic coefficient of friction values for fabrics made with conventional polyester fibers and fabrics made with polyester fibers in which PTFE had been incorporated according to the present invention. Sleeves 5 made from conventional fibers and Sleeve 6 made from PTFE-enhanced fibers were tested in this Example. These sleeves were made or knitted in the same manner as Sleeves 2 and 1, respectively, (Example 1).

15 . The coefficient of friction tests performed in this Example were sliding or pulling tests, which serve to measure the coefficient of friction of each of the sleeves. During the testing, Sleeve 5 (having fibers with no PTFE therein) was first secured to the surface of a friction-testing machine (Altek Model 9505A sold by ALTEK Company of 245 East Elm Street, Torrington, CT 06790 USA), which is equipped with a 2000 gram sliding weight. This sliding weight was placed on Sleeve 20 5, and the coefficient of friction indicator of the friction-testing machine was engaged. The pulling speed was set to 20 inches per minute, and the pulling begun. The coefficient of friction (COF) indicator of the machine gave a number for the COF. The test was repeated 6 times to obtain an average COF value for Sleeve 5. The same test procedure was employed to obtain an average COF value for Sleeve 6, the sleeve 25 containing PTFE-enhanced fibers. The COF results obtained are shown in Table 1 below:

Table 1

Test Run Number	Coefficient of Friction (COF) of Sleeve 5 (0% PTFE)	Coefficient of Friction (COF) of Sleeve 6 (5% PTFE)
1	0.25	0.22
2	0.25	0.23
3	0.24	0.22
4	0.26	0.23
5	0.25	0.23
6	0.25	0.23
Average	0.25	0.227

5 The results shown in Table 1 indicate that the knitted sleeve (Sleeve 6) made of fibers having 5% PTFE had a lower coefficient of friction than the sleeve made from fibers with no PTFE in them (Sleeve 5).

10 **Example 4: Coefficient of Friction Testing of Fabrics Made with PTFE-Enhanced Melt Spun Fibers Using Sliding Angle Testing**

 In this Example, Sleeves 7 and 8 were formed in exactly the same manner as Sleeves 5 and 6, respectively, described in Example 3 above. Thus, Sleeve 7 was made of polyester fibers having no PTFE, while Sleeve 8 was made from
15 PTFE-enhanced polyester fibers according to the present invention. The COF testing procedure used in this example involves a sliding angle test to study the frictional properties of each of the sleeves, and to determine the static coefficient of friction for each sleeve. A Sliding Angle Coefficient of Friction Tester (Model # 32-35) was used for this purpose. In the tester three different counter surface materials were used:
20 (1) Mylar film; (2) printing paper (70# opus gloss); and (3) treated C-184 foil.

 To begin the testing, Sleeve 7 was secured to a weight. The counter surface material was placed into a holder in the sliding tester. Then, weighted Sleeve 7 was properly positioned on the counter surface material in preparation for measuring its sliding angle. The counter surface was raised from one end to
25 determine the angle at which weighted Sleeve 7 began to slide. The measurements were repeated 5 times, so that an average value for the sliding angle could be

calculated for Sleeve 7. A COF value was calculated from the average sliding angle value. These measurements and COF calculations were repeated for each of the three different types of counter surfaces.

- The same testing procedures were employed for Sleeve 8 (having
5 PTFE-enhanced polyester fibers according to the present invention). The results of the testing for this Example are shown in Table 2 below:

Table 2

Sleeve and Run Number		Counter Surface and Sliding Angle		
		Mylar Film	70# Printing Paper	C-184 Foil
Sleeve 7 (0% PTFE)	1	22°	24°	17°
	2	23°	24°	17°
	3	22°	22°	17°
	4	21°	22°	16°
	5	22°	22°	16°
	Average Sliding Angle	22°	22.8°	16.6°
	COF	0.4040	0.4204	0.2981
Sleeve 8 (5% PTFE)	1	18°	23°	17°
	2	18°	23°	16°
	3	20°	23°	16°
	4	19°	20°	15°
	5	20°	20°	15°
	Average Sliding Angle	19°	21.8°	15.8°
	COF	0.3443	0.4000	0.2830

10

These results indicate that Sleeve 8, the polyester knitted sleeve having 5% PTFE incorporated into its fibers, had a lower coefficient of friction when compared to Sleeve 7 which was made from conventional polyester fibers without PTFE additives.

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Example 5: Measurement of Increased UV Protection of Fabrics Made with PTFE-Enhanced Melt Spun Fibers Using Tensile Strength Testing

In this Example, the resistance of fabrics made with PTFE-enhanced melt spun fibers to ultraviolet radiation (UV) degradation was investigated.

In one investigation, the tensile breaking strength of non-woven fibers was tested both before and after controlled exposures to ultraviolet radiation (UV)) in a laboratory instrument to simulate radiation degradation of fabrics in field use. An industry standard test procedure SAE J1885 was used. This procedure is commonly used in the automotive industry to evaluate the light fastness of automotive interior fabrics. The procedure as used in the automotive industry may use standard light exposures of 226 kJ (e.g., Chrysler Group, DaimlerChrysler Corporation, Auburn Hills, MI 48326) or 488 kJ (e.g., Ford Motor Company, Dearborn, Michigan 48126).

A PTFE-enhanced fiber material having a PTFE concentration of 2.25%, which had been prepared by incorporating 5% of a 45% PTFE master batch into the spinning melt, was used as the test material. Conventional fiber material prepared without any PTFE content was used as a control material. The tensile strengths of a test sample and a control sample were determined by loading the fibers to determine the breaking force required break the fibers. The samples were first tested prior to UV irradiation. The forces required to break the test and control sample fibers were measured to be 260 newtons and 270 newtons, respectively. These similar breaking force values indicate that PTFE-enhanced fiber and non-enhanced fiber have comparable tensile strengths.

Next, both the test and the control samples were exposed various levels of to UV lamp radiation in a laboratory wear simulator (Atlas Electric Model No. Ci4000 Weatherometer®, sold by Atlas Electric Devices Company, 4114 N Ravenswood Ave, Chicago, IL 60613). This simulator uses xenon arc lamps with up to 2X solar irradiance for accelerated weathering of test specimens. The radiation exposure levels were in the amounts of 225, 490, 600, 800, and 1100 kJ/m². With increasing radiation exposure (i.e., at 800 kJ/m²) the control sample disintegrated. However, the test sample retained its structural integrity at all exposures up to and including 1100 kJ/m². In test samples and control samples exposed to 600 kJ/m² of radiation, the breaking forces were measured to be 169 newtons (lbs./sq.in) and 85 newtons, respectively. The tensile strength reduction for the test sample and the

control sample due to UV irradiation are calculated to be about $(260-169)/(260) = 35\%$, and $(270-85)/270 = 68\%$, respectively. These results indicate that addition of PTFE to the melt spun fibers improves resistance to UV degradation by a factor of about two.

5 The tensile strength of the test sample after 800 kJ/m² and after 1100 kJ/m² of radiation was measured to be about 150 and 135 newtons, respectively. FIG. 1 is a bar graph comparing the tensile strength (lbs./sq.in.) of the two samples as a function of radiation exposure. Data in the range of 0 kJ/m² to 1100 kJ/m² of radiation exposure is shown. FIG. 2 is a bar graph showing the normalized strengths
10 of the test and control samples after radiation exposure in the range of 225 kJ/m² to 1100 kJ/m².

 In another investigation of the radiation resistance, was conducted at an independent fabric-testing laboratory (I.S. LABS, Inc, 209A East Murphy Street Madison, NC 27025). At this laboratory, the tensile strength of PTFE-enhanced and
15 control materials was measured using the conventional textile industry procedure (SAE J1885). The parameters measured included the breaking tenacity and elongation at breaking load. These parameters were measured before and after light exposure under a fadeometer. The post light exposure measurements were carried out after exposing the test material to 488.8 kJ of light in an Atlas Weatherometer
20 instrument. Samples from four different product categories were tested. Product categories 1 and 3 (labeled as 1/150/100 and 1/150/50 control products, respectively) were sleeves knitted from yarn with no PTFE additives, respectively. Product categories 2 and 4 (labeled as 1/150/100 and 1/150/50 PTFE products, respectively) were sleeves knitted from PTFE-enhanced yarn. The successive numbers in a label
25 respectively refer to the ply, denier and number of filaments in the yarn. Thus, the 1/150/100 label refers to a one-ply, 150 denier, 100 filament yarn. The PTFE concentration in both the 1/100/100 and 1/100/50 PTFE-enhanced fibers was estimated to be about 1.75%. In each product category, tube yarn (i.e., yarn that is not knitted or woven into a fabric) specimens, and yarn unraveled from sleeves knitted
30 from the product yarns were tested.

The test results for the various product categories are shown in

Table 3.

Table 3

5

Product category		Breaking Tenacity (g/denier)	Elongation at breaking	Comments
Product 1 1/150/100 Control	Tube yarn (calibration)	4.2	24%	
	Yarn unraveled from unexposed sleeve	3.6	17%	
	Yarn unraveled from exposed sleeve	1.0, 0.08, 0.07	12%, 0.2%, 0.3%	3 sample measurements
Product 2 1/150/100 PTFE	Tube yarn (calibration)	4.2	22%	
	Yarn unraveled from unexposed sleeve	4.0	23%	
	Yarn unraveled from exposed sleeve	3.3 0.2 0.05	21%, 0.3%, 0.06%	3 sample measurements
Product 3 1/150/50 Control	Tube yarn (calibration)	4.3	24%	
	Yarn unraveled from unexposed sleeve	4.2	25%	
	Yarn	3.2,	0.5%,	3 sample

	unraveled from exposed sleeve	0.2, 0.2	0.7%, 0.3%	measurements
Product 4 1/150/50	Tube yarn (calibration)	4.1	22%	Average of 2 measurements
	Yarn unraveled from unexposed sleeve	3.9	22%	Average of 2 measurements
	Yarn unraveled from exposed sleeve	1.6, 1.4, 1.5	12%, .9%, 14%	3 sample measurements

In Table 3, the first row in each product category refers to an instrument calibration or reference measurement of tube yarn. The second row refers to measurements of yarn unraveled from the sample sleeves before they were exposed to the test light exposure in the Atlas Weatherometer instrument. Similarly the third row refers to measurements on yarn unraveled from the sample sleeves after light exposure in the Atlas Weatherometer instrument. The last measurement was repeated on three separately unraveled strands of yarn for each product category.

The scatter seen in the test results on unraveled yarn from both exposed and unexposed sleeves may be related to the weave or knitting structure of the textile fabrics from which the sleeves are made. The results however on the whole indicate that fibers with a concentration of PTFE additives are significantly stronger than fiber without PTFE additives.

15 Example 6: Improved Moisture Management Properties of Fabrics Made with PTFE-Enhanced Melt Spun Fibers.

In this Example, the moisture handling or management capabilities of fabrics made with PTFE-enhanced melt spun fibers were investigated. The moisture handling or management capabilities of fabrics were determined by measuring the extent of capillary wicking in strips of fabric that were dipped in a water solution.

The water was conveniently colored, which allowed visual observation of the wicking water front as the fabric absorbed water. The colored water solution was prepared by adding green food dye to water in a beaker. The amount of dye added to the water was sufficient to raise the conductivity of the dye solution to be about 1000 Mhos \pm 100 Mhos.

Two PTFE-enhanced fiber fabric strips (labeled PTFE-1 and PTFE-2) were tested. The two strips were tested along with two control fabric strips, Control-1, and Control-2, respectively. Test samples and control fabric samples were cut into 1 inch wide by 8 inches long strips. The strips were conditioned in a 65% \pm 2% humidity atmosphere at about 70° Fahrenheit for at least 4 hours immediately prior to testing. The fabric strips were held vertically over the water solution with their ends dipped in a beaker of the colored water solution. One inch of the bottom end of the test fabric strip was submerged in the dye solution. A stopwatch was started when the bottom one inch of the fabric strip was submerged in the colored water solution. The upward wicking of the colored water into the fabric strip was observed. The times it took for the wicking water front to rise up to marks that were 1 inch, 2 inches and 3 inches above the submersion level in the beaker were timed using the stop watch. Two runs were performed on each fabric using a new fabric strip piece for each run.

The timing measurements on the various samples are listed in Table 4.

Table 4

Sample		Time to 1" Mark	Time to 2" Mark	Time to 3" Mark	Comments
PTFE-1 (1/150/50)	Run 1	2"	35"	8'30"	Water front remained just below 3" mark for the last 2 minutes of the run
	Run 2	2"	36"	8'30"	Reached 3" mark by 5 min and stopped.
Control-1 (1/150/50)	Run 1	8"	41"	10'	Reached 2 ¾" inch mark by 6 min and stopped.
	Run 2	6"	38"	7'40"	uneven wicking at 3" mark
PTFE-2 (1/150/100)	Run 1	9"	26"	2'57"	
	Run 2	7"	30"	2'30"	
Control-2 (1/150/100)	Run 1	5"	33"	2'42"	
	Run 2	5"	28"	2'12"	

The water wicking front in many instances, as described in comments
 5 column of Table 4, did not rise beyond the 3" level evenly or consistently. This
 indicates that under the test conditions the fabric strips were saturated with water to a
 steady state level before or at about the 3" mark. However, the PTFE-enhanced
 fabrics consistently showed faster water wicking up to the 1" and 2" levels than the
 control fabrics did. For example, in the PTFE- 1 strips wicked water up to the 1"
 10 level in about 2 seconds compared to about 6 to 8 seconds observed in the Control –1
 strips. Similarly, the PTFE- 2 strips wicked water up to the 2" level in an average of
 about 28 seconds compared to an average of about 30.5 seconds observed in the
 Control –2 strips. These test results indicate that fabrics made of PTFE- enhanced

yarns may have moisture management properties that are superior to those of fabrics fabricated from yarn without PTFE-additives.

5 Example 7: Abrasion Testing of Fabrics Made with PTFE-Enhanced Melt Spun Fibers.

 In this Example, the abrasion resistance properties of fabrics made with PTFE-enhanced melt spun fibers were evaluated. The abrasion properties were evaluated using a conventional Taber testing method that is used for evaluating textiles. The method involves holding a piece of textile fabric on a base plate of a test
10 unit and repeatedly running a wheel under load across the textile fabric surface to wear it down. The weight of textile fabric piece is measured before and after the test. The weight loss due to wear is an indication of the abrasion resistance properties of the fabric.

 A sample fabric made from PTFE-enhanced fibers was tested. The
15 fabric was made with a 1/150/100 PTFE-enhanced yarn. The sample was tested along with a control fabric sample made with conventional yarn without PTFE additives. These samples (labeled PTFE-3 and Control-3, respectively) were wear tested on a commercial instrument (Taber Abraser Model 503, sold by Taber Instruments Corporation, North Tonawanda, NY USA). Each fabric sample was weighed prior to
20 testing. The fabric sample then was held on the base plate of the instrument by vacuum. A wheel (H-10 size) was run over the surface of fabric sample for 200 cycles. The wheel was loaded with 500 grams of weight.

 General visual observation suggested that the wear of both PTFE-enhanced fabric and control fabric was similar under the test conditions. Closer
25 observation of the tested samples using a digital camera showed that the PTFE-enhanced fabrics were smoother after wear than the control fabrics. The fabrics were weighed after the wear to obtain quantitative measurement of the amount of wear. Each fabric type was tested four times. The test data for the various fabric samples are listed in Table 5.

Table 5

150/50 Control vs. PTFE

Sample 1/150/50 Control-3	Wear Cycle	Wheel number	Load grams	Wt. Before g	Wt. After g	Wt. Loss g
Run 1	200	H-10	500	7.2915	7.2743	0.0172
Run 2	200	H-10	500	7.3687	7.3555	0.0132
Run 3	200	H-10	500	7.3576	7.3436	0.014
Run 4	200	H-10	500	7.3362	7.3254	0.0108
Average Wt. Lost						0.0138 (19%)

5

Sample 1/150 /50 PTFE-3	Wear Cycle	Wheel number	Load grams	Wt. Before g	Wt. After g	Wt. Loss g
Run 1	200	H-10	500	7.3064	7.2932	0.0132
Run 2	200	H-10	500	7.2697	7.2585	0.0112
Run 3	200	H-10	500	7.2713	7.2589	0.0124
Run 4	200	H-10	500	7.295	7.2868	0.0082
Average Wt. Lost						0.01125 (15%)

The average weight loss in the PTFE-enhanced fabric sample (15%) was about three quarters of the weight loss in the conventional control fabric (19%). These test results indicate that textile fabrics made with suitable content of PTFE-enhanced yarns may have better abrasion resistance properties than fabrics made from yarn without PTFE-additives.

In another series of tests, wear testing of a PTFE-enhanced fabric sample (PTFE-4) and a control sample (Control-4) was conducted according to General Motors standard method GM 2794 for non-woven carpet applications. The tests were conducted using a H-18 size wheel under a 1000 g load. The PTFE-4 sample for non-woven carpet applications was made from 18 decitex PET fiber having a PTFE content of about 2.25% (similar to the PTFE-1 and 2 samples above) and containing about 1.5% of color pigment. The control sample was fabricated from undrawn PET fiber (80 decitex). The PTFE-4 sample was subject to 2000 wheel

cycles of wear. The Control-4 sample was subject to only 600 wheel cycles of wear as by that time it had disintegrated and roughened sufficiently to interfere with wheel motion. Both samples were weighed before and after the wear cycles. The test results are shown in Table 6.

5

Table 6

Sample	Wear Cycles	Wt. Before g	Wt. After g	Wt. Loss grams	Wt. Loss %
PTFE-4	2000	13.8850	13.3835	0.5015	36.11%
Control-4	600	9.8820	9.5500	0.3320	41.2%

The test data shows that the PTFE- 4 sample even though subject to a larger number of wheel cycles of wear (2000 v. 600) showed less wear than the control-4 sample. Accordingly, PTFE-enhanced fibers may be expected show less wear than conventional fibers in non-woven carpet applications.

Example 8: Coefficient of friction Testing of Textile Fabrics Made with PTFE-Enhanced Melt Spun Fibers.

In this Example, static and kinetic friction characteristics of fabrics with PTFE-enhanced melt spun fibers in them were evaluated according to the ASTM D-1894-00 with modified weights. An ALTEK Coefficient of Friction Test Instrument (sold by ALTEK Company of 245 East Elm Street, Torrington, CT 06790 USA) was used for this purpose. In general the testing apparatus is similar to the slide and pulley arrangement described in Example 3, above. In the test procedure, a fabric-covered metal slide is slid on a fabric-covered steel platen. The slide is pulled across the steel platen at a constant speed. The force to get the sled started (static) and to maintain motion (kinetic) is measured using a strain or force gauge. The gauge readings are divided by the weight of the slide to obtain raw static and kinetic friction numbers. These numbers are converted to coefficient of friction numbers by reference to instrument calibration values using a 2000 gram standard metal sled (COF = scale reading x 2000)/slide weight).

30

Two PTFE-enhanced fiber fabrics (labeled PTFE-5 and PTFE-6) were tested. The two fabrics were made from 1/100/50 and 1/150/100 PTFE-enhanced yarns, respectively. Samples from these PTFE-enhanced fiber fabric strips were tested along with samples from two control fabrics (labeled Control-5 and Control-6) that were made from conventional fiber.

For the friction testing, square pieces of fabric (2.5" x 2.5") were cut and attached to the bottom surfaces of slides (i.e. the metal sled blocks). Another rectangular piece of the same fabric (4"x 12") was attached to the surface of a steel platen. Each slide was slid or pulled on the steel platen at a speed of about 5"/min. Starting or initial strain gauge readings at the start of slide motion were recorded as a measure of static friction. Average visual strain gauge readings over a 3" run of the moving slide were recorded as a measure of kinetic friction. Three different slide weights (obtained by adding 100 gram and 200 gram weights on top of a slide) were used for the friction testing. The three slide weights used including the attached fabric weighed about 184, 284 and 384 grams respectively. Each fabric was tested four times with each slide weight. The test data (strain gauge readings) and the scaled coefficients of friction (strain gauge readings x 2000/slide weight) are shown in Tables 8 and 9. Tables 8 and 9 also show the percentage improvement in COF for each of the PTFE-enhanced fabrics tested relative to the control fabrics.

Table 8

Sample	Slide Weight					
	184.42 g		284.39 g		384.43 g	
	Static	Kinetic	Static	Kinetic	Static	Kinetic
Control-5						
Run 1	0.0650	0.065	0.0975	0.0925	0.1350	0.1300
Run 2	0.0675	0.065	0.1025	0.0950	0.1275	0.1260
Run 3	0.065	0.065	0.1020	0.0950	0.1250	0.1250
Run 4	0.0625	0.062	0.1000	0.0950	0.1250	0.1225
Average	0.065	0.06425	0.1005	0.094375	0.128125	0.125875
Avg. COF	0.7048 36	0.69670 4	0.70675 11	0.6636779	0.6665366	0.654831 6

Sample PTFE-5	Slide Weight					
	184.44 g		284.4 g		384.45 g	
	Static	Kinetic	Static	Kinetic	Static	Kinetic
Run 1	0.600	0.0525	0.0925	0.0825	0.1150	0.1075
Run 2	0.0575	0.0560	0.0925	0.0850	0.1125	0.1050
Run 3	0.0575	0.0550	0.0850	0.0800	0.1150	0.1050
Run 4	0.0575	0.0550	0.0875	0.0825	0.11100	0.1050
Average	0.0581 25	0.054625	0.089375	0.0825	0.113125	0.1056 25
Avg. COF	0.6302 86	0.592334	0.6285162	0.5801688	0.5885031	0.5494 863
Improve ment relative to Control- 7	10.59%	14.99%	11.075	12.59%	11.71%	16.09%

Table 9

Sample Control- 6	Slide Weight					
	184.94 g		284.93 g		384.75 g	
	Static	Kinetic	Static	Kinetic	Static	Kinetic
Run 1	0.0550	0.0535	0.0825	0.0810	0.1050	0.1025
Run 2	0.0540	0.0515	0.0800	0.0785	0.1200	0.1075
Run 3	0.0510	0.0510	0.0825	0.0800	0.1050	0.1075
Run 4	0.520	0.0510	0.0785	0.0785	0.1075	0.1060
Average	0.0530	0.05175	0.080875	0.0795	0.109375	0.105875
Avg. COF	0.57471 3	0.561158	0.568741	0.559072	0.568995	0.550787

Sample PTFE-6	Slide Weight					
	184.84 g		284.77 g		384.86 g	
	Static	Kinetic	Static	Kinetic	Static	Kinetic
Run 1	0.0350	0.0350	0.0525	0.0500	0.0700	0.0675
Run 2	0.0360	0.0340	0.0525	0.0510	0.0680	0.0660
Run 3	0.0340	0.0325	0.0520	0.0495	0.0675	0.0650
Run 4	0.0340	0.0325	0.0510	0.0490	0.0675	0.0650
Average	0.0347	0.0335	0.0520	0.049875	0.06825	0.0658
	5					75
Avg. COF	0.3768	0.363262	0.365682	0.350738	0.355053	0.3426
	16					97
Improve ment relative to Control-6	34.40%	35.23%	35.67%	37.23%	37.61%	37.80 %

The data in tables 8 and 9 are also shown as comparative bar graphs in FIGS. 3 and 4. The data confirms that addition of PTFE to fibers reduces the coefficient of friction of textile fabrics.